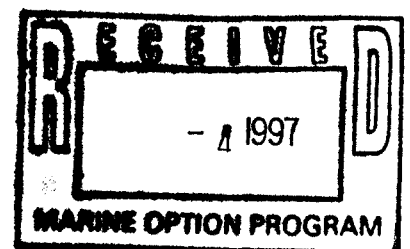


CULTIVATING HAWAII'S ORNAMENTAL FISH INDUSTRY

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September 20, 1996



INTRODUCTION

As the world's human population skyrockets past the 5 billion mark, and expected to reach 8 billion by 2025 with no sign of slowing down, it is natural for one to be concerned as to how the world's human population will feed itself. Though the population is exploding, the worldwide fish catch has leveled off, and collapsed in many areas. While the Green Revolution of the 1940's, 1950's, and 1960's stemmed the tide that was heading for world famine, the coming Blue Revolution may be the future's answer to empty tables.

The "Blue Revolution" refers to the growing prominence of aquaculture, both in the U.S. and abroad. "Aquaculture" refers to the culture of aquatic plants and animals for man's benefit. Aquaculture takes many forms; *ogo* culture on Oahu's North Shore, *Nori* seaweed culture in Japan's inland sea, trout farming in Idaho's cold, clear water, raft culture of oysters in Jamaica, shrimp megafarms in Ecuador, traditional carp culture in China, catfish farming in Mississippi, and aquarium fish culture in Singapore.

Worldwide, aquaculture is taking off as producers seek to fill the demand for seafood. With fish production more than doubling from 6.6 million metric tons in 1966 to 14.5 million metric tons in 1988 (HDLNR, 1993), it is clear that aquaculture is not a trend to be taken lightly. The United Nations forecasted that annual production could reach 22.2 million metric tons by the year 2000 (HDLNR, 1993).

In the United States, aquaculture is easily the fastest growing segment of agriculture, having grown about 20% per year through the 1980's. Between 1980 and 1990, the wholesale value of aquacultural products has risen almost four fold (HDLNR, 1993). While the aquaculture industry currently supplies about 17% of the U.S. seafood supply, production is expected to increase to about 572,000 metric tons by the year 2000. For comparison, 1988's total production was about 328,000 metric tons (HDLNR, 1993).

Currently, the State of Hawaii, led by the Aquaculture Development Program (ADP), Sea Grant Extension Service (SGES), and the USDA Center for Tropical and Subtropical Agriculture (CTSA) is trying to expand aquaculture in the State. There are many reasons for this;

- Hawaii has available natural resources, a good infrastructure, and suitable human resources to support aquacultural development throughout the islands.
- Hawaii's rate of fish consumption, about twice that of the Mainland, and preference for high quality, fresh fish, supports aquacultural development.
- The worldwide demand for aquacultural products is expected to increase, offering Hawaii a potential export product.
- Aquaculture is proving to be a growing, necessary, long-term industry.

-Aquaculture is perfectly suited to compliment plant crop production, as fish actually improve the quality of irrigation water by adding nitrates, thus getting double use out of given volume of water. (HDLNR, 1993).

In addition to these given reasons, it is also worthy of notice that Hawaii has a long-standing tradition of aquaculture, with an extensive system of fishponds throughout the State.

Generally this project dealt with aquaculture. Specifically, though, it dealt with the establishment of the Hawaii aquarium fish industry. Worldwide, the ornamental fish industry is valued at between \$4 billion and \$8 billion a year, and is rapidly growing (ERS, 1995). In Florida, the United States' greatest ornamental fish producing state, the farm gate value of ornamental fish and plants is currently valued to be about \$46.7 million wholesale a year (Corbin and Young, 1995). Foreign imports of ornamental fish and plants to the U.S. are reported to have grown from \$36 million wholesale in 1991 to and \$56 million wholesale in 1995. Between the same years, U.S. exports grew from \$12 million to \$20 million (Corbin and Young, 1995). Because of these reasons, the Hawaii SGES and CTSA have made ornamental fish production to be a "priority one" (out of three priority categories) development project, along with other proven industries such as abalone, salmon, prawns, shrimp, oysters, sturgeon, and tilapia (HDLNR, 1993).

It seems perfectly logical that Hawaii should become a center for ornamental fish production. Hawaii's climate is perfect for ornamental fish culture, since the fish do not have to be brought indoors at any time of the year, as Florida growers do during the winter months (Corbin and Young, 1995). Additionally, Hawaii is much closer to the Mainland U.S., the world's biggest aquarium fish market, than Hong Kong, Taiwan, and Singapore, the world's greatest producers of ornamental fish. This translates to shipping costs that are significantly less than those of those from Southeast Asia. There is an even greater savings when one considers that shipments of fish produced in Hawaii do not face the import duty fees that fish produced in Asia do. Additionally, shipping fees from Hawaii to Western Europe are almost half of those charged when shipping from Asia to Europe (HDLNR, 1993). Finally, fish shipped from Hawaii will pass through fewer middlemen than Asian fish, and closer proximity to the market translates to the ability to pack fish more densely and results in fewer deaths in shipment. These are all such great advantages that savings in shipping costs can outweigh the high cost of doing business in Hawaii (HDLNR, 1993).

In addition to Hawaii's shipping advantage, Hawaii already has a market distribution system in place for marine tropical fish. This system could be used to distribute freshwater ornamental species as well. Hawaii-produced fish could then be exported to the Mainland and Europe. Exporting the fish is advised, since the local market is considered to be too small to support a potentially large industry (HDLNR, 1993).

Securing loans to start an aquaculture business is rather difficult, as it is considered to be a high-risk business, with only the Bank of Hawaii currently issuing loans in Hawaii. Additionally, the Hawaii Department of Agriculture (DOA) has a revolving aquaculture

loan fund, and the Hawaii Department of Business, Economic Development, and Tourism (DBEDT) has a Capital Loan Fund that can be utilized by potential producers (HDLNR, 1993). The DOA's loan program, unfortunately, does not include ornamental fish production, since its loans can only be used for the production of food or fiber products. Aquacultural operations should, however, be reevaluated by loaning institutions, since 3 out of 5 production operations last 5 years or more, as compared to 1 in 5 for all businesses (HDLNR, 1993).

There are more reasons why Hawaii has the potential to become an important center for aquaculture, and ornamental fish culture in particular. The first reason is land and water availability (Corbin and Young, 1995). More than 600,000 acres in Hawaii are suitable for aquaculture, with little slope and with a reliable supply of quality water (Corbin and Young, 1995). The second reason is technical support. With more than 100 faculty in the University of Hawaii system who are experts in aquaculture-related fields, and with the highest concentration of aquaculture consultants in the U.S., producers have quite a pool of expertise to draw from. Hawaii also has a large labor pool of educated people to draw on, people who are well equipped to handle the technological aspects of fish husbandry (HDLNR, 1993).

Aquaculture also pairs nicely with year-round plant cultivation such as that practiced in Hawaii. Aquaculture allows a grower to use a given amount of fresh water twice: the first time to grow fish, and the second time to irrigate crops. Water from fish tanks and ponds is rather high in ammonia from fish feces, especially the sludgy water that is siphoned from the bottom. While it is toxic to fish, this ammonia-rich wastewater is ideal for irrigating crops, as it supplies both nitrogen and organic matter in addition to the pure water. Aquaculture wastewater has been used to irrigate crops in the orient for centuries. In modern times, fishpond wastewater is sometimes used to grow such food crops as lettuce, tomato, and cucumber hydroponically, that is, without the use of soil (Rakocy et al; 1992). These aquaculture-plant farm relationships are probably the best way to utilize fish tank wastewater, since the enriched water cannot legally be drained directly into a natural body of water.

THE INTERNSHIP

My internship program focused on supplying growers with broodstock of ornamental freshwater fish. The project took place at the aquaculture facility at Windward Community College in Kaneohe, Hawaii (see map). There I worked under the direction of Brian Cole, who is in charge of the facility and its operations. The project was financed by the USDA Center for Tropical and Subtropical Agriculture (CTSA), and administered by the University of Hawaii Sea Grant Extension Service and the Department of Land and Natural Resources (DLNR) Aquaculture Development Program (ADP).

The facility consists of a small metal shed which serves as an office and work area, a larger shed which serves as a hatchery and a work area, and a small supplies shed. There are 9 tanks, each about 10 feet in diameter and about 4 feet deep, and 2 tanks which measure 5 feet in diameter and 4 feet deep. The tanks were made either of welded, high-density polyethylene (HDPE) or polyvinyl chloride (PVC)-lined plywood bent into a circle to form the sides. These tanks were mostly used for rearing fry prior to distribution to farmers. Additionally, there were 9 small, tarp-lined earthen ponds, each measuring 15x15x4 feet, one pond that measured about 50x14x5 feet, and one pond that measured about 20x10x5 feet. These ponds were used to hold broodstock. There were also five holding tanks, where fish were kept that were going to be used for immediate breeding purposes or distribution. Each pond and tank, except for the smaller holding tanks, had a constant supply of fresh water, dechlorinated on the facility in a header tank which was aerated to evaporate the chlorine. Each tank and pond also had a supply of low pressure air to prevent nighttime anoxia.

The focus of the project was to supply farmers with broodstock of selected varieties of fish, as well as technical assistance. These species include:

Red Wag Sword (<i>Xiphophorus helleri</i>)	Appendix A (Axelrod et al; 1989) illustrates many of these species.
Pineapple Sword (<i>Xiphophorus helleri</i>)	
Neon Sword (<i>Xiphophorus helleri</i>)	
Rainbow Shark (<i>Labeo erythrurus</i>)	
Albino Rainbow Shark (<i>Labeo erythrurus</i>)	Appendix B (Axelrod et al; 1989) describes certain characteristics of the various species.
Red Tail Black Shark (<i>Labeo bicolor</i>)	
Tinfoil Barb (<i>Barbodes schwanenfeldii</i>)	
Black Ruby Barb (<i>Puntius nigrofasciatus</i>)	
High Fin Rosey Barb (<i>Puntius cochonius</i>)	
Gold Gourami (<i>Trichogaster trichopterus</i>)	
Blue Gourami (<i>Trichogaster trichopterus</i>)	
Pink Kissing Gourami (<i>Helostoma temminckii</i>)	
Giant Gourami (<i>Osphronemus gourami</i>)	
Pangasius (<i>Pangasius sutchi</i>)	
Pacu (<i>Colossoma bidens</i>)	

These fish were provided on an as-needed basis, free of charge, to farmers throughout the State. Additionally, technical support was provided to them via on-farm assessments by SGES personnel. Further support was provided the farmers by ongoing series of workshops taught by ADP personnel and hired consultants. Workshops offered during the summer of 1996, which I attended, included water quality management, use of a microscope to identify pathogens, and marketing of ornamental fish.

As an intern, my job was to learn as much as possible about the general operation of the ornamental aquaculture project. Many of the things that I did were a one-time experience, others were quite routine. My responsibilities ranged from inducing the fish to spawn, to repairing pumps and tanks; from seining a pond for *Pangasius* to operating a weed eater.

FEEDING

On a daily basis, I fed the fish, checked representative water samples for water quality parameters, such as dissolved oxygen (D.O.) and pH, and water temperatures. Feeding the fish consists of measuring the proper amount of the proper variety of feed, be it float on top, flake-type, or medicated, for each species in a pond or tank. Additionally, feeding entailed the hatching and culture of brine shrimp (*Artemia* sp.), and using them to feed the pre-juvenile fry.

Feeding was done daily, and in the case of fry, it was done twice daily. We used four basic kinds of feed. We used commercially-produced "swim up", a fine-grained, floating feed to feed the very young fish, and also the swordtails. Slightly larger "number two" feed was suitable for bottom feeding fish, such as rainbow sharks. A floating pellet feed, called "float", was used to feed larger fish, such as *Pangasius*, pacu, giant gourami, and tinfoil barb. These feeds may either be administered by broadcasting over the water, or by being distributed by an automatic, clockwork-powered feeder. Additionally, we fed live brine shrimp larvae to the fry as a first feed, and later weaned them to commercial feed. The brine shrimp larvae are natural food to the fry, who can see them wiggle around. The grower can feed the brine shrimp larvae and "swim up" to the fry at the same time. In this way, the fry learn to associate the "swim up" with their natural food. In a few weeks, the grower may discontinue the hatching and feeding of brine shrimp.

Brine shrimp cyst are purchased in dehydrated form, packed in nitrogen-filled cans. To hatch them, we measured 70 ml of cysts and put them into a brine solution in a well-aerated tank constructed for the purpose (see appendix C). After being in this solution for 18-24 hours, the brine shrimp hatch. In order to collect them for feeding purposes, we put a cardboard box on the top half of the tank, leaving the bottom half uncovered. The brine shrimp larvae are attracted to the light at the bottom of the tank, while the unhatched (and unpalatable) cyst float at the top. A valve at the bottom of the tank separates the live brine shrimp, leaving the undesirable cyst and shells in the tank.

WATER QUALITY MANAGEMENT

Chemically checking the water at various ponds and tanks involved using a Hach brand kit to detect changes in the color of water samples in order to determine the ammonia toxicity of the water. Water quality checks were always made in the early morning, when the dissolved carbon dioxide (CO₂) was highest, and the dissolved oxygen (D.O.) was lowest. It was vital to check these two parameters at the same time, as a high pH (pH 9.0 or above) will cause the ionized NH₄ ammonia to become toxic unionized NH₃ ammonia when the extra H atom on the NH₄ dissociates to join a hydroxyl (OH) group. A high ammonia level in itself is nothing to worry about at pH levels of below 9.0, unless the temperature is unusually high. At 0.6 ppm toxic ammonia (NH₃), some fish may start dying in a few days. Damage to the gills and kidney, reduction in growth, brain damage, and lowered blood-oxygen carrying capacity are possible as a result of long-term exposure to NH₃ levels as low as 0.06 ppm (Durborow et al; 1992). Finding the chemical tests exceed recommended parameters called for increased fresh water flow through the pond or tank in order to flush out the old water and replace it with fresh water (Durborow et al; 1992).

Checking the D.O. was a precautionary measure to ensure that the fish would not suffocate and was accomplished by sticking the probe of an oxygen meter in the water of certain ponds and tanks, and recording the results. At no time during my internship did the D.O. fall to a dangerous level. Temperature checking was done by reading a minimum-maximum thermometer and recording the results. If we had colder water, or were in a temperate climate, the thermometer would tell us if we needed to put a heater in the water, but for us it only served as a source of data for future reference.

Each week, in addition to my daily chores, I also had to clean the leaves and debris from the main water filter. Cleaning the filter consisted of turning off the water pump, closing valves at both the intake and the discharge sides of the pump, opening up the filter housing, and simply emptying the accumulated debris onto the ground. This was followed, of course, by putting it all back together, opening the valves, and turning the pump back on.

SPAWNING

Among the more important things that we did at the facility was to provide "seed", or starter, fish to farmers. We were able to do this by breeding the fish and giving out the fry to farmers. Fish breed at certain times of the year, and certain fish breed all year round if conditions are suitable. The easiest fish to breed are the livebearers, such as the swordtails. These fish give birth to live young, and will be quite prolific in a normal pond system in Hawaii's warm climate. Livebearers require little attention in this area, and are commonly grown by less sophisticated means (Cole et al; 1996).

Labyrinth fishes, such as the gourami, are egg layers. They are rather unique in their reproduction in that the male builds a floating "bubble nest" which are used to float

the slightly negatively-buoyant fertilized eggs. The female lays one egg at a time in the water, which is quickly fertilized by the male sperm. The eggs will hatch in just a few days. Gourami will breed in a normal aquaculture pond setting, but mortalities are high. After determining the "readiness" of the females by looking at the size of the abdomen, we put each of dozens of male/female pairs in separate aquaria. None of the aquaria had either aeration or fresh water coming in, as a calm surface is essential for maintaining the bubble nest. The labyrinth fishes don't require water aeration, since they are able to respire with the aid of *labyrinths*, a lung-like structure that allows these fishes to get most of their oxygen by "gulping" at the surface. Because these types of fish successfully breed on their own, without hormone-inducement, we had only to provide them with ideal, calm conditions.

Many fish, typically those native to streams, won't breed in an artificial pond setting. These fish are more difficult to breed, and must be induced to ovulate by a technique known as "dry stripping". In this method, the farmer must first determine the readiness of the females by calming them by putting them into a bucket with quinaldine solution. The farmer then inserts a thin tube through the ovipore (female), into the ovary, and siphons out sample eggs for examination under a microscope. If the examiner finds that a majority of the eggs contain an off-center nucleus (signifying that the egg is ready to join with a sperm) the fish is judged "ready" and is set aside. Males are judged ready to mate if a bit of milt, or sperm, can be squeezed out of the genital papillea. Following the determination that the fish are ready to mate, the farmer will decide exactly when he wants to dry strip them, or remove their eggs and sperm in order to artificially fertilize the eggs. Timing is essential. If the farmer wants to dry strip the next day at noon, he will give both the breeding males and breeding females muscular injections of a mixture of the hormones HCG (Human chorionic gonadotropin) and carp pituitary (Rottman et al; 1991, no. 424) at about 2 am and again at about 6 am. As the scheduled time for ovulation approaches, the fish are checked every half hour for ovulation, or egg release. At about 12 noon the next day, both the males and the females should be ready to dry strip (Rottman et al, 1991, #423).

The actual process of dry stripping involves first drying the female with paper towels and gently squeezing the grey-colored eggs out of her ovipore and into a very clean and dry bowl. The fish is then put into fresh water to recover. Immediately after this, two males (in order to assure success) are dried with paper towels and are squeezed in the abdomen in order to force the white milt out of the anus and into the bowl that the eggs are in. The males are then placed in fresh water to recover. The bowl is then swirled very thoroughly in order to assure mixing and fertilization. After the eggs and the milt are thoroughly mixed, a bit of water is added to the bowl and mixed.

The water is what actually causes the eggs and sperm to react together, and that is the reason that absolutely no water can be allowed to contact either the sperm or the eggs before they are completely mixed. If the eggs contact water before they are fertilized, the shells will harden, effectively keeping the sperm from fertilizing them. If the sperm gets wet, the sperm will be prematurely activated (Rottman et al; 1991, no. 421)

After the water is added to the mixture, the mixture is placed in a McDonald jar, a device meant to simulate the natural water movement and buoyancy of a stream, to hatch. Hatched fry are then placed in well-aerated aquaria.

HATCHING TO NURSERY POND

After the fry are hatched in the hatchery, they are extremely fragile and are left to grow for a few days or more, depending on the plans that the grower has. When it is decided that the fry need to be placed in outdoor tanks, the grower must acclimate them slowly to the temperature and the pH of the tanks. If the temperature difference between the aquaria and the tank differs by as little as 3 degrees centigrade, it is likely that the temperature shock will kill the fry. To minimize the danger, the grower can carefully siphon (using a fine mesh screen to avoid siphoning up the fry) the excess water out of the aquaria and carry the aquaria outside to be floated in the tank. The grower should also allow a bit of tank water into the aquaria, so that the sudden change of pH will not shock the fry. After a half hour or so, the temperature of the water in the aquaria will be equal to the temperature in the tank, and the fry will have grown accustomed to the higher pH of the tank. The fry can then be emptied safely into the tank.

FACILITY MAINTENANCE

Occasionally it was necessary to repair a tank or the PVC lining of a pond. This was accomplished by applying a polypropylene patch to the damaged area using PVC cement. Cracked aquaria were repaired by running a bead of silicone sealant along the crack.

When fish are removed from a pond or tank for whatever reason, we normally would clean the tank in order to minimize the presence of pathogens. Cleaning a tank first involves draining it by removing the drain pipe so that the water would drain out of the hole on the bottom. Draining a pond involves the use of a gasoline-powered pump. The water was discharged onto the ground, where any lingering fish can't escape into stream and thus become menace alien species. After draining, a very small amount of powdered chlorine was sprinkled around the tank or pond and was very thoroughly scrubbed with a broom. The tank or pond was then thoroughly rinsed out and drained before being refilled and stocked.

HARVESTING

When fish were to be moved from one pond or tank to another, or caught for breeding purposes, they had to be seined out using a net. Pond seining is essentially a two-man operation, though one worker can do it in a tank. Seining requires two people to move the seine along opposite sides of the pond, keeping the bottom of the seine on the bottom of the pond by using poles on both sides of the seine. As the seine is dragged along the bottom, fish will be "herded" in front of the net. At this point, one worker must get

down on hands and knees and pull in the weighted bottom, called the leadline, of the net, while the other worker stands behind him and pulls in the top line, called the floatline. At this point the second worker must either hold the net by himself in such a way that the fish cannot escape the seine or enlist the help of a third worker to hold one side of the seine, while the first worker removes the fish with a dip net.

SHIPMENT

In order to ship the fry to growers, fry were put into large, about 1.5 gallon, heavy plastic bags, filled halfway with water. The fry were not packed very densely, in order to prevent injuries in shipping. The bag was filled 1/3 full with water, then inflated with bottled oxygen and tied tightly at the top. The bag was then then placed in a styrofoam-lined cardboard box. Generally, the longer the duration of the shipment, the less densely the fish were packed into the bags, in order to avoid anoxic conditions.

Being an intern had few perks, but one perk that I did enjoy was the opportunity to attend classes held by the ADP for free. The first workshop that I attended dealt with marketing ornamental fish.. The speaker, Ed Taylor, was a hired consultant from Florida that advocated Hawaiian ornamental fish growers to form a guild in order to implement quality control measures, standardizing shipping standards (such as a standardized "bag" of fry), and convincing the Department of Agriculture to relax quarantine standards at Honolulu International Airport so that it can be effectively utilized as an international fish transfer station. Later, I attended a workshop that was meant to familiarize growers with the use of a microscope in order to identify diseases in fish. The workshop also taught various disease-control measures. Finally, I attended a workshop that dealt with practical aspects of water quality control.

DISCUSSION

My interest when I started this internship was in identifying a branch of agriculture that had a lot of room for growth. I reasoned that with the skyrocketing human population, and with the total worldwide fish catch leveling off in the last twenty years after centuries of growth, aquaculture could not only provide me with a career, but could also do its share in alleviating human suffering. Because of various things that I had read at that time, I became convinced that man could no longer count on the wild fish catch in order to supply him with the fish he demands.

Since most food fish are quite at home in the ocean, I wished to learn more about cage aquaculture, a form of fish culture in which a net cage is the home for cultured fish, typically sea bream or salmon. I felt that it would be possible to raise valuable fish such as mahi mahi in sea cages in Hawaiian waters, and Atlantic cod in New England waters.

In speaking with people in the aquaculture industry about this, not one of them gave me any words of encouragement, despite the fact that the method has been and is successful throughout Asia, Canada, the Middle East, and especially Europe. People almost universally told me that I could not possibly obtain all of the necessary permits that would be required in Hawaii. It was a common feeling that Hawaii would not permit the construction of unattractive fish cages within the view of valuable seaside real estate. Waters farther out at sea would be too deep to anchor a cage. One person had researched the idea herself years ago and finally gave up because the waters around Hawaii aren't suitable for this purpose, since the currents are so strong that cages cannot be effectively anchored. Another person told me that the cash outlay for these cage operations is so huge that only a large corporation can afford to finance them.

Even if Hawaii is not a good location for this type of aquaculture, Hawaii can still profit by expanding its ornamental fish industry. With the new emphasis in the State on diversifying the economy, and more specifically, diversifying agriculture, Hawaii has little to lose and much to gain by developing its aquaculture potential.

EVALUATION

The internship that I completed has done much more than given me a lot of technical knowledge. More importantly, I have gained a certain feel for aquacultural operations. It is one thing to read about how to dry strip fish, it is quite another to actually do it. I am much better prepared to start an ornamental fish operation than I ever would be after having read all the books written on the subject. It is clear to me that an aquaculturist must be multi-talented, since the operation of an aquaculture facility requires knowledge of many disciplines, from plumbing to accounting to chemistry. I am also more aware of the risks involved in this type of aquaculture.

In addition to experience with aquacultural operations, I gained valuable experience in writing reports and proposals, photography, equipment repair, and the use of standard herbicides.

I also found that I prefer to work in a small group, rather than alone. The hours seem to drag when I have to work alone.

I gained experience in handling setbacks, such as when we weren't successful at breeding the Pangasius. If I had experienced such a setback while working on my own operation, I might have been so disappointed that I would want to give up before I lost any more money. I now understand, though, that such failures happen and it is just part of the game.

ACKNOWLEDGEMENTS

I would like to thank my sponsor, Brian Cole, for sponsoring me and teaching me most of what I've learned during my internship.

I would also like to thank Rich Bailey for teaching me so much, and for getting me into the ADP workshops for free.

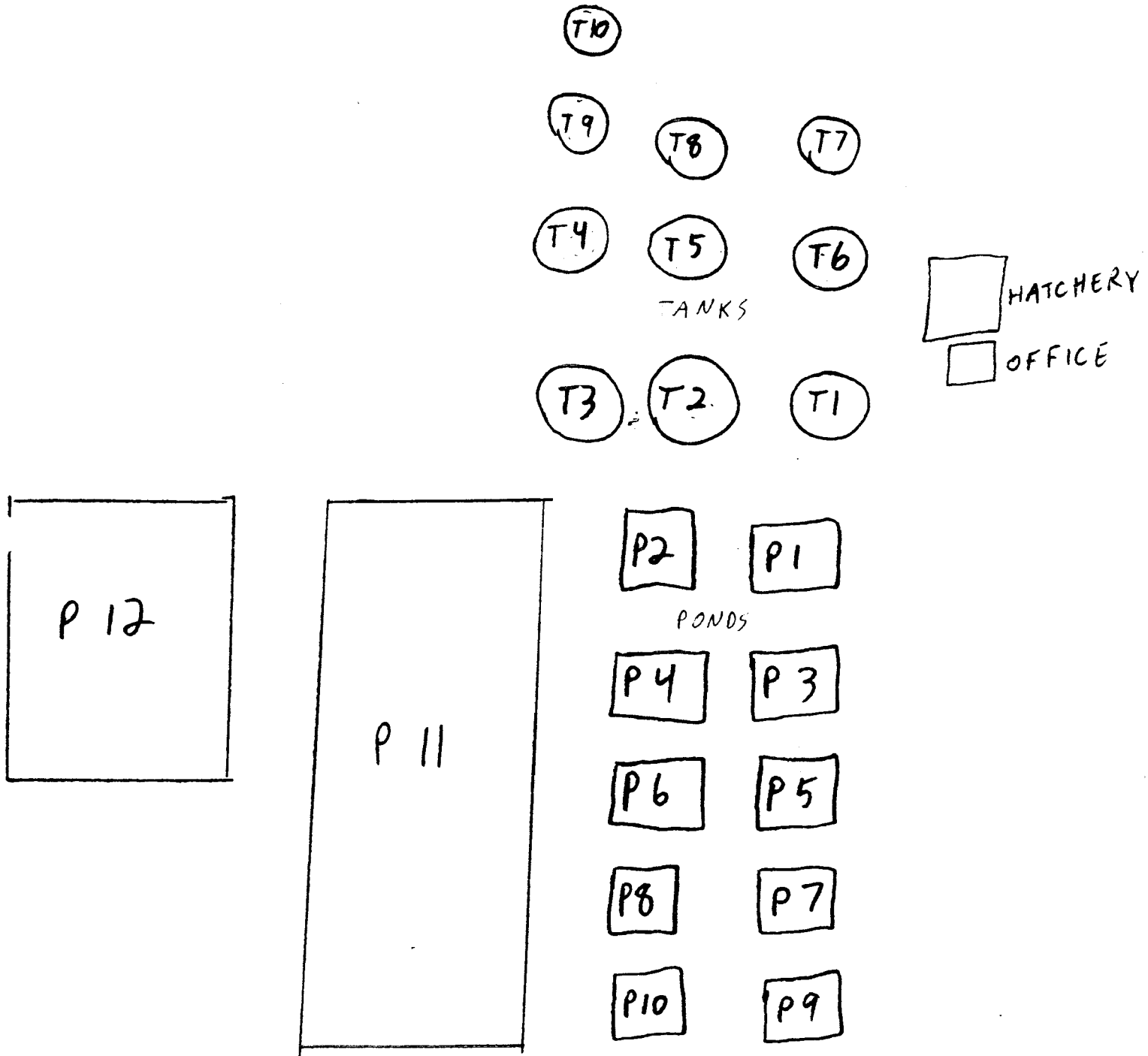
I would like to thank the University of Hawaii's Marine Option Program for providing me with this internship opportunity, and for providing me with stipend money.

Finally, I would like to thank Sherwood Maynard for guiding me in the writing portions of this internship, and for making time to see students, including myself. This seems to be rare among the administrators of this University.

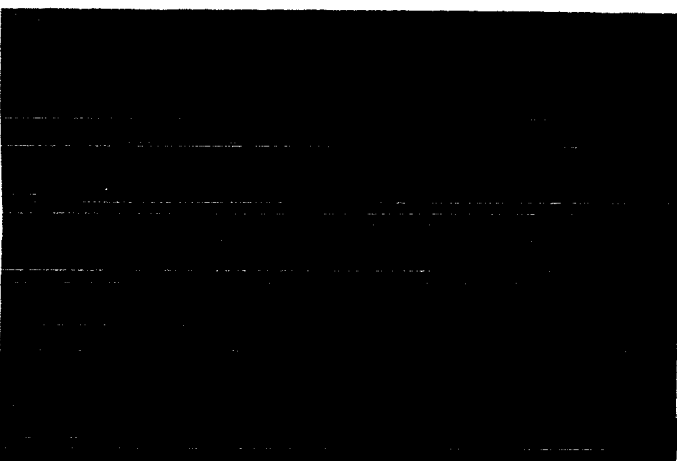
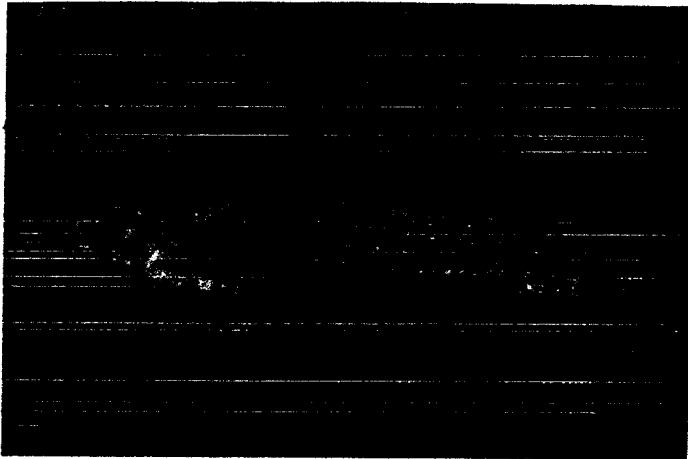
WORKS CITED

- Axelrod, H.R., W.E. Burgess, N. Pronek, et al; 1989. Dr. Axelrod's atlas of freshwater aquarium fishes, third edition. TFH Publications, Neptune City, NJ.
- Cole, B., R. Bailey, and C. Tamaru. 1996. A manual for commercial production of the swordtail, *Xiphophorus helleri*. University of Hawaii Sea Grant Extension Service. Honolulu.
- Corbin, J.S. and L.G.L. Young. 1995. Growing the Hawaii aquarium products industry. Aquaculture Development Program. Honolulu.
- Durborow, R.M., D.M. Cosby, and MW. Brunson. 1992. Ammonia in fish ponds. Southern Regional Aquaculture Center publication no. 463.
- Economic Research Service, US Department of Agriculture. 1995. Aquaculture: situation and outlook report.
- Hawaii State Department of Land and Natural Resources. 1993. Hawaii's future in Aquaculture. Aquaculture Development Program, Honolulu.
- Rakocy, J.W., T.M. Losordo, and M.P. Masser. 1992. Recirculating aquaculture tank production systems: integrating fish and plant culture. Southern Regional Aquaculture Center publication no. 454.
- Rottmann, R.W., J.V.Shireman, and F.A. Chapman. 1991. Determining sexual maturity of broodstock for induced spawning of fish. Southern Regional Aquaculture Center publication no. 423.
- Rottman, R.W., J.V. Shireman, and F.A. Chapman. 1991. Hormonal control of reproduction in fish for induced spawning. Southern Regional Aquaculture Center publication no. 424.
- Rottmann, R.W., J.V.Shireman, and F.A. Chapman. 1991. Introduction to hormone-induced spawning of fish. Southern Regional Aquaculture Center publication no. 421.

MAP OF THE WINDWARD COMMUNITY COLLEGE AQUACULTURE FACILITY



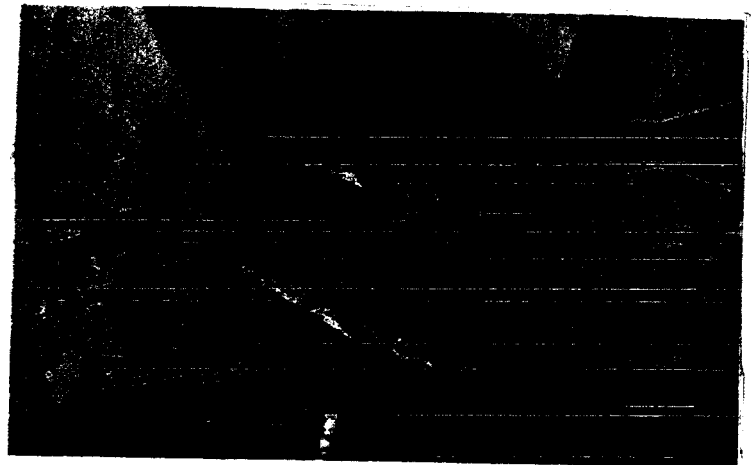
APPENDIX A



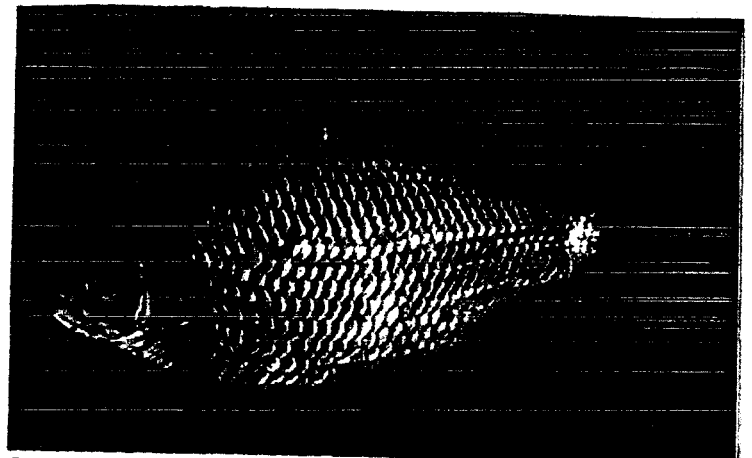
Xiphophorus helleri pH7.3;H14;25C;13cm;60L ♀ ➡ ○ ♥ 📷 📺



Labeo bicolor pH7.5;H10;26C;12cm;200L ♀ ➡ ○ ♥ 📷 📺

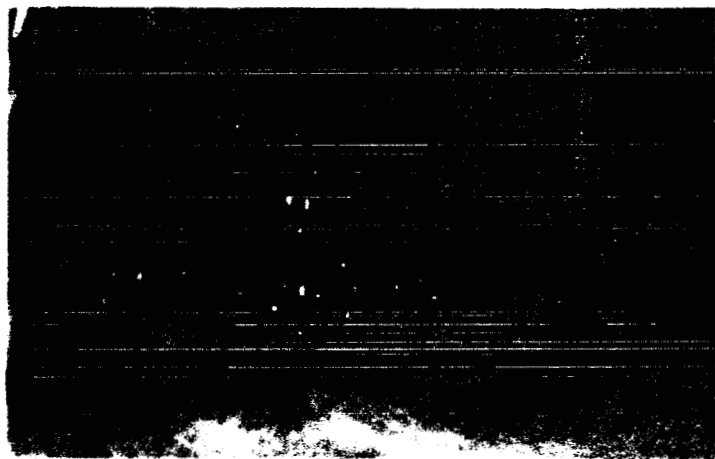


Labeo erythrurus pH7.5;H10;27C;12cm;200L ♀ ➡ ○ ♥ 📷 📺



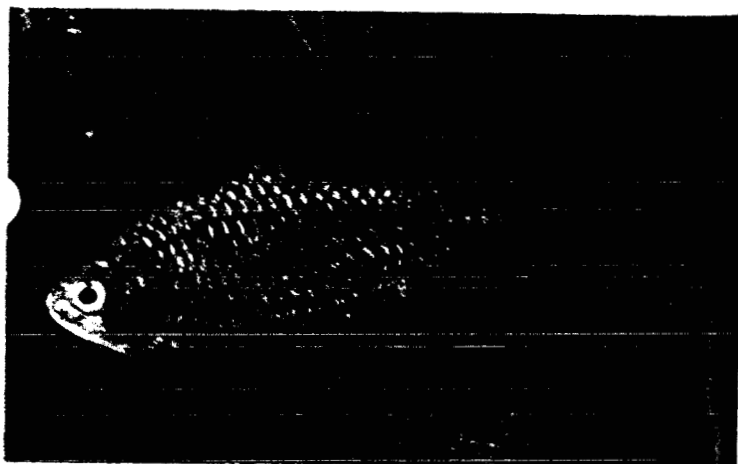
Barbodes schwanenfeldii pH6.8;H5;25C;40cm;400L ♀ ➡ ○ ♥ 📷 📺

APPENDIX A



Puntius nigrofasciatus pH7.2;H5;26C;6cm;40L ♀ ♂ ♀ ♂ ♀ ♂

Trichogaster trichopterus pH6.8;H6;27C;15cm;200L ♀ ♂ ♀ ♂ ♀ ♂



Puntius conchonius pH7;H6;26C;15cm;80L ♀ ♂ ♀ ♂ ♀ ♂



Helostoma temminckii pH7;H10;26C;30cm;400L ♀ ♂ ♀ ♂ ♀ ♂



Pangasius sutchi pH6.8;H8;27C;18cm;200L ♀ ♂ ♀ ♂ ♀ ♂







Osphronemus goramy pH7;H8;27C;60cm;800L ♀ ♂ ♀ ♂ ♀ ♂




APPENDIX B

An explanation of the symbols used in Appendix A




FEEDING HABITS

-  Dry, packaged food
-  Live worms, Daphnia, etc.
-  Live fish
-  Vegetarian



REPRODUCTION

-  Egglayer
-  Livebearer
-  Mouthbrooder





AQUARIUM LIGHTING

-  Bright with occasional sunlight
-  Bright, no sunlight
-  As dark as possible as long as fishes are visible





TEMPERAMENT

-  Peaceful community fish
-  Not recommended for beginners

AQUARIUM SET-UP

-  Densely planted aquarium
-  Rocks; no plants
-  Only gravel on bottom
-  Rocks, plants and driftwood

SWIMMING HABITS

-  Bottom swimmer
-  No special swimming level
-  Top swimmer
-  Swims in middle of water

pH = Relative acidity/alkalinity of water. Above 7.0 is alkaline. Below 7.0 is acidic.

H = Hardness of water according to German scale. The lower the number, the softer the water.

C = Temperature in degrees Centigrade.

cm = Maximum length to which the fish grows (in centimeters).

L = Capacity (in liters) of smallest aquarium in which fish may be kept.

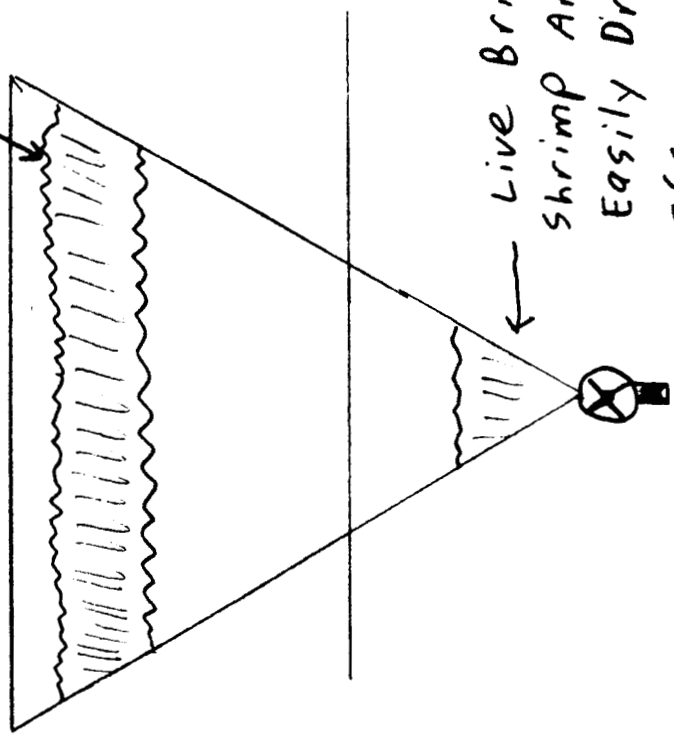
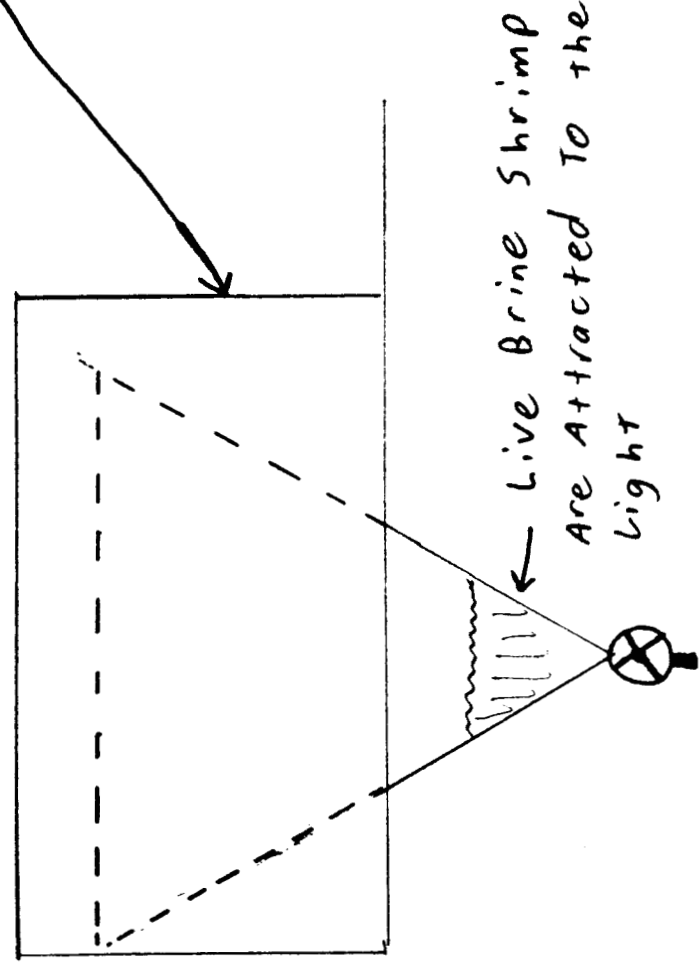
BRINE SHRIMP HATCHERY

APPENDIX C

ARTEMIA sp.

Cardboard Box Blocks
Out Light At The Top.

Dead Shrimp
remain floatin
At the
Top.



Live Brine
Shrimp Are
Easily Drained
Off Through
The Bottom
Valve